Enablers, Equippers, Shapers and Movers: A typology of innovation intermediaries' interventions and the development of an emergent innovation system

Enablers, Equippers, Shapers and Movers: *A Typology of Innovation Intermediaries Interventions and the Development of an Emergent Innovation System*

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Abstract

Innovation intermediaries are seen as crucial and critical players in the development of emergent high-tech sectors, though their understanding is not holistic and it depends on geographical and sectoral specificities. This paper empirically deploys a recently developed classification within a case study of the New Space Sector in Scotland, a previously peripheral region within Space Industry, now emerging as a global leader. Based on secondary document analysis and mixed-method empirical research using primary data from surveys, interviews and social network analysis, this study examines: a) the make-up of the innovation intermediation organisations in Scottish Space Sector, b) their sectoral positioning through innovation networks and c) the interventions they deploy and effects they expect to have on the sectoral actors. Based on this analysis, a new typology of Innovation intermediaries' interventions is proposed, to link them with their identified systemic roles of enablers, equippers, shapers and movers.

Keywords: Innovation Intermediaries, Intervention Typology, New Space, SMEs

Introduction

Innovation intermediaries are seen throughout the innovation studies literature as key players in the development of emerging economic sectors and activities. In particular, intermediaries' knowledge brokerage function has been examined in detail, though many authors agree that the overall understanding of the functions of innovation intermediaries is fragmented and hard to operationalise (Abbate, Coppolino, & Schiavone, 2013; Dalziel, 2010; Hannon, Skea, & Rhodes, 2014; Howells, 2006; Van der Meulen et al., 2005). Building on an extensive literature review, a new classification for analysing these organisations and their roles within geographically-bound sectoral systems of innovation (GSSI) was already developed based on a more inclusive the definition of innovation intermediaries, a shift in focus from "roles" to "interventions", and proposing a new eight-part classification of innovation intermediaries' interventions [1]. However, to examine the applicability of this emerging classification for addressing the real-life challenges of fragmentation and inoperability mentioned above, empirical deployment of the classification in contemporary case studies and dynamic analytical settings is required. Furthermore, we need to link the classified interventions with wider contextual positioning and mandates of innovation intermediaries, to expand from the classification framework's analytical into a normative function, useful for policymaking and organisational management.

Opportunities to develop such studies are extensive since the lack of understanding of innovation intermediary roles has been identified in many industry sectors. This is noted not only by analysts but also by practitioners, who often find themselves unable to operationalise the state of the art analysis offered in the literature. A recent example of a detailed sectoral analysis of the roles of innovation intermediaries can be found in Hannon, Skea and Rhodes [2] analysis of the UK Energy Sector. Space Sector, too, presents a great opportunity for such analysis since it can be used as an excellent comparative model for many high tech industries, and is currently undergoing an industry transition towards Open Innovation, which bring the role of innovation intermediaries to the fore. Specifically, Venturini and Verbano [3] mention several understudied aspects of technology transfer and innovation intermediation in the Space Sector, advocating for an

> *"[…] Analysis of the intervention of brokers (including private) and other organizations devoted to facilitate the transfer such as incubators, venture capital companies, science and technology parks;"* (Venturini & Verbano, 2014:109).

The pressing need for further understanding of these organisations is growing in particular in the "New Space" segment of the sector, where economic development seems to depend on models of intermediaries-facilitated open innovation processes inside Living Laboratory-like loose configuration of actors [4,5]. Hence, building on my past work in the Scottish New Space sector based on participatory action research of this selected GSSI, I propose to develop a typology of the established classes of interventions, which takes into consideration new empirical findings related to practitioners concerns and their policy requirements as well as operational constraints [6].

I choose the emerging Space Sector in Scotland as the most optimal context in which to develop the typology parameters, as this field satisfied the above methodological requirements, has the appropriate size and make-up of the system and is timely concerning the developmental trends present in this region and sector. Though vary of significant contextual influences on sectoral makeup [7], the intensity of intermediaries' presence in this sector is likely due to political impetus and relatively large up-front investment costs. This led to a rich set of examples enabling for a high level of completeness of our study.

In this paper, my methodology is combining recently proposed classification framework based on extensive literature review [1] with empirical evidence from extensive and sustained ethnographic observation [8], a sector-wide social network analysis (SNA) [9] and a set of in-depth case studies [10]. It is important to note that I am undertaking a two-phase approach to this inquiry, basing the identification of the sectoral features and roles of innovation intermediaries from the perspective of the recipients of their interventions, i.e. SMEs in the Scottish Space Industry. This part of the research is composed of a series of in-depth qualitative interviews with members of management teams based on a study of SMEs' innovation networks and new product development processes. I am then moving on to interrogate secondary literature and survey selected intermediaries' staff to illuminate their fit within the established understanding and the developing typology.

This paper begins with a brief presentation of the already developed innovation intermediaries classification, in particular, focusing on the relationship between innovation intermediaries interventions and systemic roles, thus proposing a typological model. After describing the methodology of this study, I outline the make-up of the innovation intermediation provision in the Scottish Space Sector through a broad mapping exercise. I will first describe their sectoral positioning through SNA analysis of innovation networks. Then, I will outline selected case studies of the key interventions deployed in the sector, based on ethnographic work, secondary document analysis and a small survey of staff. Finally, in the discussion section, the case studies are explicitly linked to the four-fold typological understanding of high-tech innovation intermediation interventions, as *enablers, equippers, shapers* and *movers*.

Aims: Building an Innovation Intermediaries' Interventions Typology

Innovation intermediaries' typologies are abundant in the existing literature. For instance, working in the agricultural sector in Kenya, Kilelu et al. [11] identify four different types of innovation intermediaries as Systemic Brokers, Technology Brokers, Enterprise Development Support and Input Access-Focused Intermediaries. There is another similar typology derived empirically by Colombo, Dell'Era and Frattini [12], who propose four types of innovation intermediaries as Connectors, who gather information regarding the experience and competences, Brokers, who identify the sources of knowledge, Collectors providing solutions and Mediators who are establishing relationships. Another such typology is forwarded by Kim [13] who describes four overarching "roles" as Knowledge enabling, Facilitating relations, Facilitating learning, Managing Interfaces. Although these typologies might be functional for the analysis they are developed for, they are based on two problematic premises required for a more holistic study of the field: a potentially incomplete definition of innovation intermediaries and a functional focus on distinct "roles" rather than examining (mixes of) interventions.

For instance, a detailed analysis of innovation intermediation literature, by comparing and contrasting examples of past attempts at classification of the various intermediaries' tools [11,13–18], led to the

establishment of a new structured classification of innovation intermediaries' interventions, as shown in Table 1 [1].

1. **Resources** – provision of infrastructure and tools for use by innovation stakeholders
    a. **Infrastructure** – provision of system-level nationwide resources
        i. **Space** – networked provision of physical space for use by stakeholders
        ii. **Knowledge** – systemic provision knowledge (IP) for deployment in innovation processes
    b. **Tools** – provision of specific deployable resources
        i. **Equipment** – provision of specialist or otherwise inaccessible tools and devices
        ii. **Skills** – provision of expertise, advice and workforce
2. **Activities** – active engagement in defining and developing future innovation products
    a. **Framing** – activities deployed to facilitate wider system development
        i. **Interaction** – active development of opportunities for engagement of stakeholders
        ii. **Translation** – active brokerage between stakeholders and identifying development trends
    b. **Project –** activities on the level of a specific innovation projects to interlink stakeholders and further specific innovation pathways
        i. **Work** – active engagement with innovation projects and investment of staff effort
        ii. **Capital** – active deployment of resources (financial or otherwise) to an innovation project

Table 1 - Innovation Intermediaries' interventions classification.

Most intermediaries will deploy a mix of the described resources and activities, whilst focusing on several key target intervention areas. The resulting eight classes of interventions corresponded to the noted three "division lines" within the literature. These are based on the differences between the type of action deployed: splitting "activities" to enact a strong development vision versus developing and deploying innovation-enabling "resources"; "social" and "physical" interventions: i.e. the difference between deploying soft / relational or hard / material resources and activities; and employing high level or low level of direct involvement in the development.

However, expanding the definition and focusing on intermediaries' interventions can leave the proposed framework exposed to lack of analytical and operational linkage to the organisational context within which they are deployed. Hence, a proto-typology linked to this classification was derived using the links between these divining lines in the literature and additional contextual factors related to their emergence. In particular, four main contextual factors were identified analytically as Close Involvement, Systemic Investment, Soft Leadership and Strong Mandate [1]. These four respectively correspond to loose pairings of intervention classes as Project and Infrastructure; Infrastructure and Tools; Tools and Framing; and Framing and Project. These groupings are also related to the tensions between the financial commitments in acquiring and deploying resources and political commitments in proposing and delivering activities, moderated by a specific ecosystem's evolution from emergence to maturity. However, these factors by themselves do not form a functional typology, as an additional understanding of their rationales and manifestations within the interventions is needed.

Examining the literature, some of several functional typologies have been formed. Kilelu et al. define six functions to innovation intermediaries interventions as "demand articulation/stimulation, network brokering, knowledge brokering, innovation process management, capacity building and institutional building" [11] and Klerkx and Leeuwis [19] pose innovation intermediaries as solving five challenges: demand articulation, developing resources and competencies, dealing with market failures, financing, and overcoming system failures. Combining these key insights from the literature, I propose that the overarching innovation intermediaries' interventions intentions can be framed as roughly four-fold:

1. To remove barriers for innovation by providing resources and action to address bottlenecks and challenges, with typical core intervention classes being Skills Resources and Capital Activities.
2. To proactively create conditions encouraging innovation, with stimulus, promotion and investment with deploying Space and Equipment Resources.
3. To create motivation for the innovation, especially by assisting in the development of markets, often external to the sector, through Interaction and Translation Activities.
4. To enact a particular vision for the future of the activity in a sector through delivering Work Activities and deploying Knowledge Resources.

Further integrating these intentions with the previously framed four proto-typological contextual factors: levels of investment or involvement and strength of vision/mandate or leadership; I propose a new typological model for contextual deployment of innovation intermediaries intervention as having four main types of roles/mandates:

1. Removing Barriers - Close Involvement – **Enabling the ecosystem**
2. Encourage Innovation - Systemic Investment – **Equipping the players**
3. Creating Motivation - Soft Leadership – **Shaping the common vision**
4. Enacting visions - Strong Mandate – **Moving the development**

These types of approaches to innovation intermediation cover a very wide range of actual deployment configurations of the classes of interventions, a deeper understanding of which would be necessary to operationalise this model. Past research shows that addressing such challenges is very context-specific [7,20], depending on the sector, the (local) environment, etc. which leads to the vital role of GSSI framing for any specific analytical or operational study. Hence, in the rest of this paper, the derived typology will be tested within a specific context - the Scottish New Space Sector. In particular, I will be using a multi-method data collection and analysis to validate the key differentiating aspects of the four innovation intermediaries types.

Methodology

The initial empirical investigation of the innovation intermediaries in the Scottish Space Sector was completed deploying participatory ethnographic research [21–23] and document analysis [24]. Specifically, I was part of an innovation/business development team, which was just developing an innovation intermediation intervention. Moreover, I took part in several dozens of industry events, formal and informal; conducted an extensive survey of the available literature and documents, in particular as related to innovation policy and sectoral economic indicators; and analysed patterns of activities, most of which are presented elsewhere [25]. Such work has been conceptualised as "strategic ethnography" [26] and is inspired by the Biographies of Artefacts and Practices approach [27,28]. This work produced a detailed understanding of the "lay of the land" when it comes to innovation intermediaries, in particular, due to their central role in the sectoral development and integration [4,5]. However, to understand the position of these innovation intermediaries within the

studied sector and their significance for the sector's development, additional research focusing on the structure of innovation networks is needed.

Social network analysis (SNA) is used widely to map out innovation networks within knowledge-intensive contexts [29]. In particular, ego-centric SNA or ego-SNA, based on collecting detailed information about the individual practitioners' networks, is deployed to study the structural relationships between players in such ecosystems [30]. Unlike the whole network studies which pre-define a network and then survey all members (nodes) within it, ego-SNA focuses on surveying a single originator node (ego) and its connection (ties) to others (alters) [31], through the open-ended name-generation process. This is based on filling out a detailed questionnaire in which characteristics of the interviewed actors partners and their relationship to them are examined. Based on this information, ego-networks (or ego-nets) can be graphed and analysed statistically. In addition, the whole network structure can be examined, if multiple ego-centric networks from the same population are joined together by assembling all ties in one network [32]. Such a composite whole network can then be used to analyse the integration of actors within the larger context of studied innovation networks within GSSI as studied in this paper. Due to the overarching interest in the role of innovation intermediaries within the system the resulting composite network was studied as an instance of a "two-mode" network [31] – one relevant node being the originating ego-nodes and the other "bridging innovation intermediaries", i.e. nodes who are of the right characteristics (entities having been identified in the earlier mapping exercise or very similar) and who are linked-to from at least two egos (in-degree centrality of more than 1).

Examining the role of various actors in integrating innovation networks can be achieved by measuring a node's centrality within the whole network. Traditional undirected centrality measures, such as closeness, betweenness and (in-)degree centrality, are inefficient in these circumstances, as they are based on network density [33]. In a composite whole network, the "originator" ego-centric nodes will always seemingly outrank all the other ones, in particularly obscuring and third-party "connector nodes" or bridges, which are nonetheless playing a potentially crucial role in integrating the whole network. These methods would also show a significant amount of "clustering" around "originator" ego-centric nodes, which is epistemically misleading for studies of composite ego-networks, since the clustering effect is not a phenomenological feature of the network, rather a result of the data collection technique. Hence, the only useful measurements of network positioning of all nodes are the rankings based on "in-degree centrality", which discriminate against the passive ego-centric "originator" nodes not linked-to from other "originators". As such, the resulting centrality ranking will reflect the interlinking of the "originators" through either any of their ego-network alter members acting as bridges or directly. Such measures, i.e. "authority" and "directed eigenvector centrality", are thus exposing the true degree of centrality of both egos as well as alter-bridges. The same goes for some of the other advanced directed centrality measures, such as the currently dominant PageRank algorithm used by search engines such as Google [34]. Hence, in the analysis of the innovation intermediaries positioning within the studied innovation network, a mix of the "authority", "directed eigenvector centrality" and PageRank was used, to show the pro-active linking paths between the ego-centric networks.

However, understanding particular nodes/intermediaries centrality is just the beginning of understanding how they got there. In particular, using a case studies approach [10,35], I examined the SNA's top-ranked innovation intermediaries' interventions, as correlated to the established four intentions/interventions areas outlined earlier. Since the particular interest in this work is the relationship between the mandate and its on the ground interpretation, supplementary data was collected using a short survey questionnaire, asking one member of staff at each targeted

intermediary to provide a Linklater scale ranking of the importance of the various intervention classes to their programme, the reason behind such focus and how it has come about.[1] These were then studied in parallel to documents about these interventions and a narrative outline of the cases was produced as a starting point for a comparative analysis of the relationship between mandate, network position and intervention operationalisation.

Results: Innovation Intermediaries in the Scottish New Space Sector

The New Space Sector in Scotland is a very interesting example of an emerging high-tech regionally-bound sectoral innovation system, which has over the past 10 years undergone a transformation from an emergent conceptualisation of opportunities in this arena to a mature industry with global recognition. The ability to chart some of the key intermediaries interventions in this sector over this evolution can illuminate not only the modelled or intended interventions classification and deployment, but crucially can track their success or otherwise in the complex socio-economic reality of a fast-paced economy.

In particular, currently, the global Space Industry is in a time of transition, from the "classical" to the so-called "New Space" era [25,36,37]. From cheapening of base technologies to miniaturisation and creation of satellite constellations to a more open and accessible satellite data, new geo-information services, enabled through Space assets, are being developed at an accelerated rate. In Scotland, this has been seized by researchers, entrepreneurs and policy-makers alike, and a vibrant sectoral innovation system has emerged. Such development was supported by a targeted set of interventions, which had a very significant impact on the sector's emergence and development in the region, supporting the establishment of regional and global primes, as well as a pan-regional value chain integration [25]. Further initiatives are currently being rolled out to support the sector's maturation and encourage growth through supporting start-ups and spin-outs.

Innovation Intermediaries in Scottish New Space Sector's Innovation Network

Examining the innovation networks established specific structural trends among the SMEs, such as increasing network density for the younger, more "New Space" SMEs and grow of the importance of public partners. However, by plotting all network edges (i.e. connections between two partners) in the same network space, it became apparent that the most central actors in the network, are organisations fitting the conceptual description of innovation intermediaries. The centrality of these organisations, connecting the diverse firms, can be seen in Figure 1.

Hence, as seen in Table 2, using the SNA's statistical measures of in-degree centrality, directed eigenvector centrality, authority and PageRank, several organisations with innovation intermediation functions were identified as the most central nodes in the network. In particular, the five most central nodes are the European Space Agency, Scottish Enterprise, UK Space Agency the Satellite Applications Catapult and Innovate UK. There are some small discrepancies in-between the exact rankings produced by the three different computational methods, as they vary in their iterative algorithms. As an analytical check-up, the undirected versions of the three computational methods were tested as well, showing consistent results – through some of the originator egos outranked them, the top alter-bridges were the five listed innovation intermediaries (the simple undirected eigenvector centrality is shown in Table 2 for reference). Apart from egos and non-private organisations listed in Table 2, in

[1] To check for completes of my understanding of the landscape, a snowball question to identify all other innovation intermediaries within the GSSI was also included. Results showed near complete alignment with the analysis resulting from my ethnographic mapping exercise.

the whole sample, there are only four other alter-bridges, which are all (larger) corporations (Airbus, SSTL, OHB and Reaction Engines).

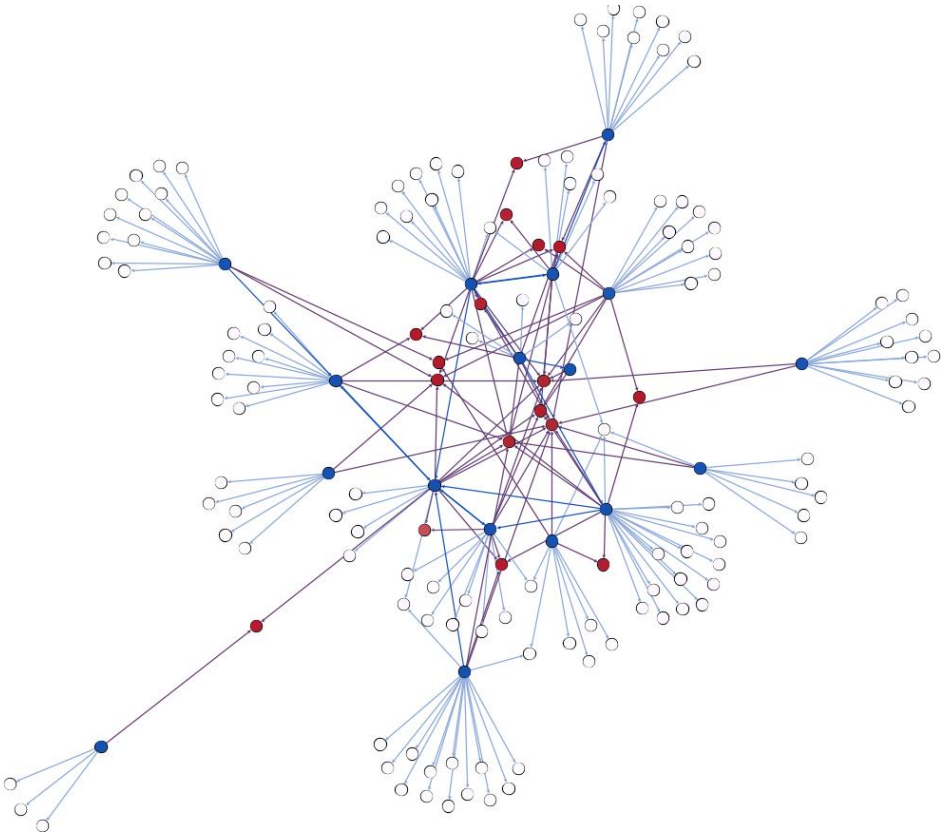

Figure 1 - Scottish New Space SMEs' innovation network, plotted with Gephi (0.9.2) software using Hu's proportional algorithm [38]*. The colours are highlighting the originating ego-centric SMEs (nodes marked in blue) and the innovation intermediaries, research centres and governmental agencies (marked in red).*

Non-Private Nodes (Innovation Intermediaries, *Research Centres* and Governmental Agencies)	**In-degree Centrality (rank) (sorted)**	**Undirected Eigenvector Centrality (rank)**	**Directed Eigenvector Centrality (rank)**	**(Directed) Authority (rank)**	**(Directed) PageRank (rank)**
European Space Agency (ESA)	11 (1)	0.75 (4)	0.79 (2)	0.40 (1)	0.010 (2)
Scottish Enterprise (1.2)	8 (2)	0.56 (8)	1.00 (1)	0.29 (3)	0.011 (1)
UK Space Agency (2.2^)	8 (2)	0.67 (5)	0.76 (3)	0.35 (2)	0.009 (4)
Satellite Applications Catapult (2.3)	6 (3)	0.48 (11)	0.72 (4)	0.25 (5)	0.010 (3)
Innovate UK (2.2)	6 (3)	0.47 (12)	0.47 (8)	0.25 (4)	0.008 (5)
University of Edinburgh	5 (4)	0.36 (16)	0.20 (35)	0.19 (8)	0.008 (6)
University of Strathclyde	4 (5)	0.40 (14)	0.63 (5)	0.21 (7)	0.007 (10)
Scottish Centre of Excellence in Satellite Applications (SoXA) (2.4)	3 (6)	0.35 (19)	0.30 (17)	0.12 (10)	0.007 (15)
Space Network Scotland (1.3)	3 (6)	0.12 (40)	0.02 (69)	0.07 (36)	0.007 (14)
RAL Space (2.3)*	2 (7)	0.21 (24)	0.61 (6)	0.09 (18)	0.007 (17)
NASA	2 (7)	0.13 (35)	0.37 (12)	0.05 (49)	0.007 (8)
DLR	2 (7)	0.15 (34)	0.03 (68)	0.09 (19)	0.006 (21)

UK Government (2.1)	2 (7)	0.16 (33)	0.12 (38)	0.08 (20)	0.006 (27)
Data Lab	2 (7)	0.19 (27)	0.10 (41)	0.10 (16)	0.006 (28)
University of Leicester	2 (7)	0.19 (28)	0.13 (36)	0.10 (13)	0.006 (31)
Scottish Government (1.1)	2 (7)	0.17 (32)	0.07 (40)	0.10 (15)	0.006 (38)
Herriot-Watt University	2 (7)	0.17 (31)	0.03 (67)	0.10 (12)	0.006 (39)

Table 2 - Top ranking innovation intermediaries extracted from the whole network of Scottish New Space Sector using applicable SNA measures of centrality.

In addition, organisational hierarchies of closely linked organisations are listed in brackets next to their names. There are, in particular, two key groupings: the Scottish Government oversees the Scottish Enterprise (development agency), who founded Space Network Scotland; and the UK Government's innovation agency, Innovate UK is the parent body of the Satellite Applications Catapult, who in turn have set up the Scottish Centre for Excellence. There are a few additional hierarchical relationships (denoted by ^ and *) - UK Space Agency is an executive branch of the UK Government, whilst RAL Space part of one of the Science and Technology Facilities Council's national laboratories, ultimately also under the responsibility of the UK Government.

Though the identified non-private alter-bridges were notionally split analytically into the innovation intermediaries, research centres and governmental agencies, focusing on innovation intermediation intervention, most will deploy such resources and deliver activities. These results show both the central position of these actors, as well as point towards a need for understanding the role(s) of their interventions within the studied regional-sectoral system of innovation. Using the ethnographic data collected earlier on characterising the most visible intervention, a small series of case studies below outline the emerging four key types of intervention as previously identified in this papers opening proposition.

Selected Innovation Intermediation Interventions' Case Studies

So far, the analysis was centred on organisations and intra-organisational relationships. However, consistent with the proposed approach to focus on innovation intermediation as a set of interventions, I argue that in order to understand the central position of innovation intermediaries within the studied New Space Sector in Scotland a deeper case-study analysis of the interventions is needed. In particular, this analysis points towards a multiplicity of intervention classes deployed simultaneously and the consequent multiplicity of roles. From a detailed case study analysis of the interventions of central SNA- mapped intermediaries (see Table 3), the four key UK/Scottish-administered programmes were identified as:

- SMART: SCOTLAND grant awards were provided to a host of upstream SMEs (STAR-Dundee, Alba Orbital) by the Scottish Enterprise. Together with the evidenced change in the innovation capabilities/culture [39], this is an "enabling" intervention. Scottish Enterprise also funded the Space Network Scotland programme/organisation to facilitate interaction across the Scottish Space Sector, which was categorised as a "shaping" intervention.
- UKube-1, the by the UK Space Agency financing and project-management of the UK's first CubeSat, built almost entirely in Scotland (by Clyde Space, Bright Ascension, Steepest Ascent). With a strong project management involvement and a specific reference to the desire to build new knowledge, this is categorised as a mainly "moving" investment.
- Scottish Space Symposium and Data.Space Conferences, which played a critical role in facilitating the interaction and translation necessary for the formation of a common identity amongst the sectoral actors, were organised by the Scottish Centre of Excellence in Satellite Applications (SoXA) – a clear "shaping" intervention. They also co-coordinate a small incubation programme at Tontine in Glasgow (an "equipping" intervention).

- Higgs Centre for Innovation, Science and Technology Facilities Council's (STFC) recently opened business incubator and innovation facility in Edinburgh, to support six new incubated companies per year for two years and offer space and expertise to other sectoral actors. With a strong focus on the provision of space and equipment, this is an "equipping" intervention.

It is important to note that in addition to the analysed case studies, there are other key intermediaries and interventions, in particular, European Space Agency (ESA) and EU Frameworks providing a focal point for the development of international standards and certification, as well as conducting their own technology transfer initiatives ("enabling"-type interventions). An example of the former is the partnership with the University of Dundee and STAR-Dundee over Space Wire and Space Fibre on-board communications protocols for satellites[2]. Another example of support for innovation not captured here, significantly important in the current maturation phase of the development of the Space Sector in Scotland, is the support for foreign investment, through UK government foreign aid programmes, such as UK Space Agency-run International Partnership Programme (IPP), as well as by deploying Scottish Development International (SDI), a Scottish Government inward investment support scheme - primarily acting in the capital investment in projects (an "enabling"-type intervention).

For instance, the former is supporting an international expansion of Earth Observation Capabilities (in particularly for Edinburgh-based geospatial-information companies Ecometrica and Carbomap) [40,41] and the latter assisted in bringing to Scotland key players from the global new space sector, for instance, Spire [42]. Specifically, the SDI/Scottish Enterprise uses the Regional Selective Assistance (RSA) mechanism to "help projects that will create or protect jobs in Scotland" [43]. Furthermore, in terms of market-creation, several other programmes are reaching into this sector, for instance, the Space for Smarter Government demonstrators for public procurement and various agencies' funding schemes for analytical and practical product and service development[3], including the recent Challenge Funding available through the UK Industrial Strategy. For instance, some project funding comes directly from Innovate UK, with their online audit tool indicating 14 projects based in Scotland were funded with a total value of over £420.000 (by 2019)[4]. These are all predominantly "enabling"-type interventions.

[2] This relates to funding from The European Space Agency (contract numbers: 17938/03/NL/LvH – SpaceFibre; and 4000102641 - SpaceFibre Demonstrator), the CEOI-ST under University of Leicester (contract number: RP10G0348A02) and the European Union Seventh Framework Programme (FP7/2007- 2013) (grant agreement numbers: 263148 - SpaceWire-RT (SpaceFibre QoS) (funding to University of Dundee) and 284389 - SpaceFibre-HSSI (VHiSSI chip) – EUR 374 995,23 for STAR-Dundee; (total value EUR 2.6M)).

[3] See: https://www.spaceforsmartergovernment.uk/

[4] For more details, please see: https://datavis.innovateuk.gov.uk/app/#/region=Scotland;sector=Emerging%20&%20Enabling;theme=Space;

Grouped Innovation Intermediation Organisations (from network analysis above)	Key Interventions	Key Characteristics	Intervention Classifications	Typological Classification
European Space Agency (ESA)	Copernicus Masters -- Direct project investment	Open international competition; Funding and other support to participants and winners -- Specific project management and funding through non-competition-based contracts for R&D	**Capital** Translation -- **Work** Capital	Enabling -- Moving
Scottish Government Scottish Enterprise -- **Space Network Scotland**	**SMART: Scotland Awards** **--** Procurement Funding -- **Space Network Scotland**	**Open regional grants scheme; Funding to successful applicants** -- Funding for SMEs and/or specific projects, through instruments such as Regional Selective Assistance (RSA) mechanism -- **Facilitating networking**	**Capital** Skills -- **Capital** -- **interaction**	**Enabling** -- **Shaping**
UK Government UK Space Agency	**UKube-1** -- Regulation -- Project funding	**Directly designed project with lead partners; Funding and project management** -- Developing a regulatory framework (policy and law) -- Funding for projects, for instance, the International Partnership Programme (IPP), Space for Smarter Government (SSG) demonstrators, etc.	**Work** Capital **Knowledge** -- **Interaction Translation** -- **Capital**	**Moving** -- Shaping -- Moving
UK Government Innovate UK **--**	Project funding and work -- Business	Management (**SoXA**) and funding (Innovate UK) of projects **--** Providing advice	**Work** Capital -- **Skills**	**Moving** **--** Enabling

Satellite Applications Catapult **--** **Scottish Centre of Excellence in Satellite Applications (SoXA)**	development support -- **Scottish Space Symposium** **DATA.SPACE conference** -- Incubation at Tontine	**--** **Series of events of regional and international reach; Facilitating networking and discussions** -- Providing business incubation space and support, events facilitation	Knowledge -- **Interaction** **Translation** -- **Space** Skills	-- **Shaping** -- Equipping
UK Government *Science and Technology Facilities Council* *RAL Space / UK ATC*	**Higgs Centre for Innovation**	**Business incubator programme and innovation facility; Funding and access to expertise and equipment, events facilitation**	**Space** Skills **Equipment** Knowledge Interaction	**Equipping**
NASA DLR	Project work	Leading (international) projects; Funding and management	**Work** **Knowledge**	Moving
Data Lab	Project work	Coordination of interaction through specific projects; Funding and management	**Interaction** **Translation** Work Capital	Shaping
University of Edinburgh *University of Strathclyde* *University of Leicester* *Herriot-Watt University*	Project work Spin-out	Involvement in specific projects; Management and access to expertise and facilities	**Work** Skills **Knowledge** Equipment	Moving

Table 3 - Cross-sectional analysis of the leading interventions by the identified central non-private organisations with intermediation function within the Scottish New Space Sector.

Sectoral Landscape of Innovation Intermediation Interventions'

Using the quantitative data collected from the surveys with selected participants in the various projects/innovation intermediaries' staff, a comparative radio-graph of the foci of individual intervention groups was created. This is based on a Linklater scale (1-5) ranking of the provision of intervention classes within the given innovation intermediation programme. The results seen in Figure 2 show close matching to the qualitative analysis performed through the case studies outlined above, with UK Space Agency's UKube-1 particularly strong in the "moving" capital domain (as well as work); Scottish Enterprise / Scottish Space Network ranked highest in the "enabling" capital, the work and the "shaping" interaction classes; SoXA being strong in many domains, covering predominantly the "shaping" interaction and translation and the "moving" work and knowledge; and the STFC's Higgs Centre for Innovation particularly strong in the "equipping" space intervention class.

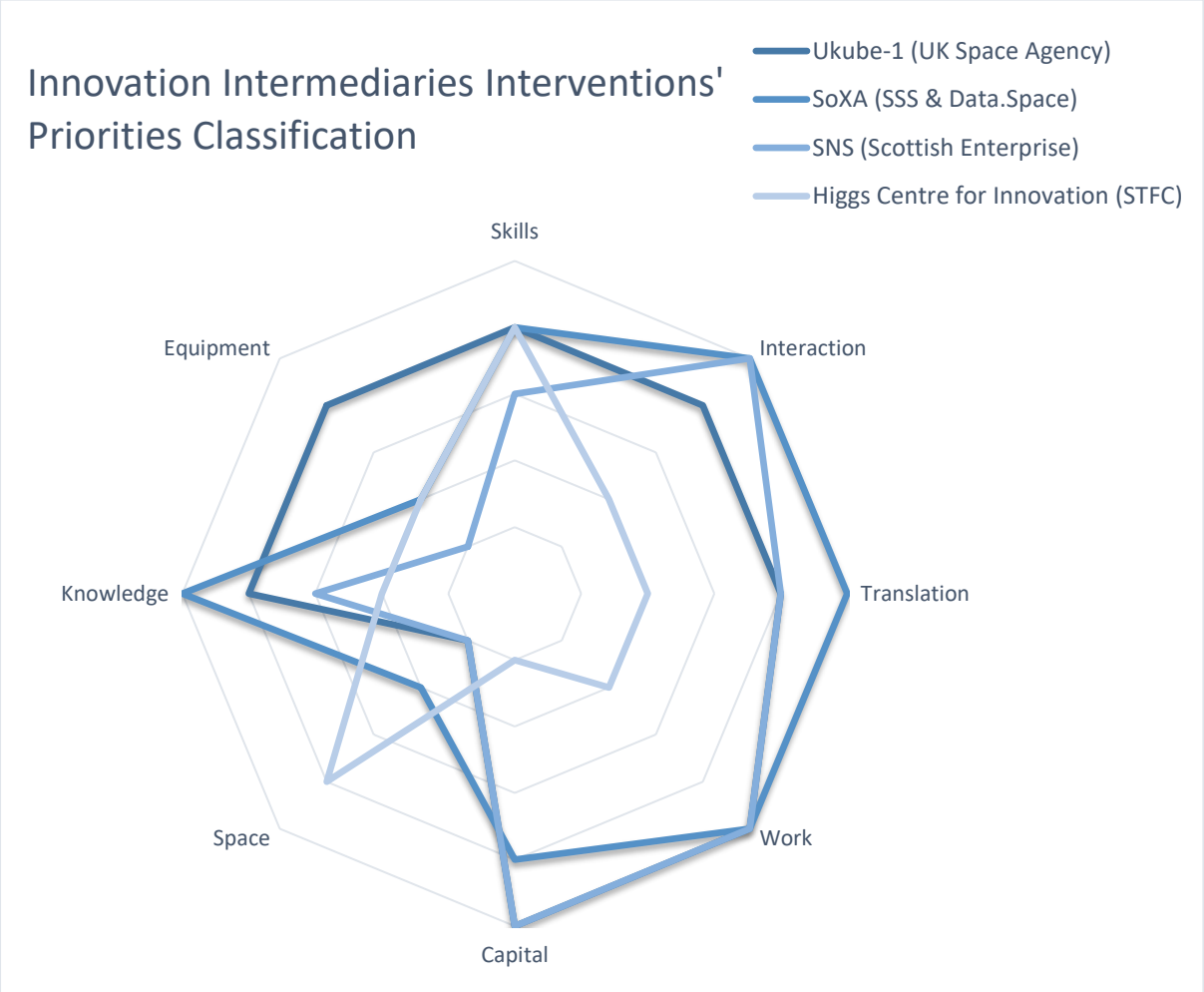

Figure 2 - Radio-graph of the survey-based mapping of selected innovation intermediaries interventions' priorities.

Furthermore, the new typology is not only analytically useful to enhance understanding but also operational/developmental tool for practitioners, both policy-makes and innovation intermediaries staff, as well as business development teams in firms and research organisations. To this end, and as part of the survey data collection with participants in the analysed case studies, additional questions about their assessment of needs for, and provision of, interventions within the Scottish Space Sector were included. Using the ranking scale of classes (1-8), the survey respondents were asked to rank the need for, and provision of, these intervention classes across the Scottish Space Sector. The results are presented on a bar chart in Figure 3. As the figure shows, capital, work and interaction classes of interventions are most well provided, whilst space is least so, and that the needs are more or less largest in these areas, too. However, using a simple subtraction, the balance of the interventions' demand and supply shows significant divergences. Most lacking is work (net difference of -1.3), the most over-provided is interaction (difference of +2.7), it is also lacking skills and equipment (-0.7), as well as space and translation (-0.3). Three seems a slight overprovision of knowledge and capital (+0.3). This show to a current strong presence of "shaping" interventions, with lack of "moving" ones.

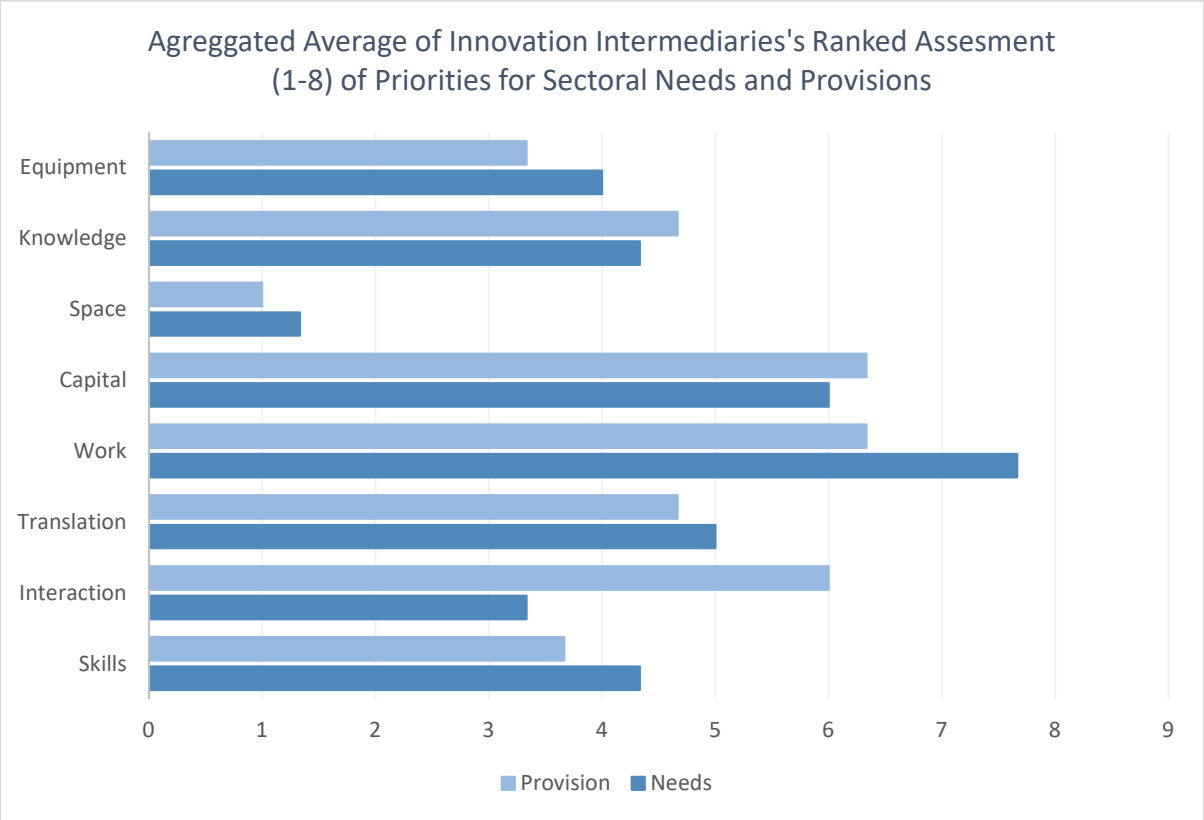

Figure 3 - Bar-chart of the aggregate averaged ranking of the need for, and provision of, innovation intermediation intervention classes within the Scottish Space Sector.

Consequently, for practitioners planning and/or assessing any intervention, a detailed needs assessment and (eco)system analysis is recommended [44], leading to the development of context-specific sets of interventions based on particular evidence-based theories of change [45]. Furthermore, answering the – what to do? question is also critically linked to performance management and assessment [46–48], and the classification presented above can also be deployed to construct evaluation exercises on intervention programmes through deployment a related classification measurable outcomes. The examples listed are illustrative and represent but a small sample of all available interventions and outcomes, with different organisations adopting a selection of which best suits the need of their sector and their goals, mandate and available resources.

Discussion and Conclusion: Innovation Intermediaries' Interventions as Enablers, Equippers, Shapers and Movers of an Emergent Innovation System

Returning to the proposed model consisting of the four main types of roles for innovation intermediation interventions and integrating it conceptually with the results of the quantitative and qualitative studies of the Scottish (New) Space Sector, the following conclusions can be drawn regarding the deployed interventions to provide the resources and activities for innovation. The innovation intermediaries' interventions are:

1. **Enabling the ecosystem** by removing barriers for innovation, with close involvement in investing capital and developing skills. Here the Scottish Enterprise's SMART: SCOTLAND grants have shown the important direct support for specific R&D projects, securing them a central role within the Scottish Space Sector innovation network, with particular impact in the early stages of its development. Other funders (Innovate UK, Scottish Government, UK Government, ESA), whose interventions are also classed here also have a prominent systemic role in bridging the actors in the network.

2. **Equipping the players** through deploying space and equipment resources as a systemic investment. In this contexts, Higgs Centre for Innovation, and the smaller SoXA-led incubator at Tontine, are particularly interesting, though their immediate reach is so far limited as they were both only set up in 2018 and they do not feature in the network, though their various "parent" organisations do. Due to significant critical mass required to warrant the associated high level of investment, the recent establishment of such interventions is likely related to the growing maturity of the sector.

3. **Shaping the common vision** through interaction and translation activities as a type of soft leadership. Scottish Centre of Excellence in Satellite Applications (affiliated to Innovate UK's Satellite Applications Catapult) and Scottish Space Network (funded by Scottish Enterprise) lead the interventions in this area, but are not as central in the innovation network, in part perhaps due to the very strong performance of their funding organisations. They exert "soft" brokerage role of predominantly facilitating interactions between actors. Given that, though the New Space segment of the sector is new, there has been existing R&D within a small number of firms and research organisation in the "traditional" space sector, these interventions normally associated with more mature sectors have instead emerged earlier and led the transition between the two "modes".

4. **Moving the development** by delivering work activities and deploying specific (new) knowledge resources, linked to a strong mandate. Here, the UK Space Agency and the InnovateUK-SA Catapult-SoXA have the strongest presence, by project managing and knowledge brokering, and leading to a critical position in integrating the network. These are directly linked to national innovation policy in this arena [25] and hence very specific funding mandate. Other (international) space agencies (especially ESA) have a similarly strong presence here, alongside the lead local Universities and other funding and research organisations. These interventions being present since the early stage of sectoral development - as well as the multiplicity of roles/intervention-types the organisation's involved deploy - lead to these organisations being very centrally placed within the innovation network.

Hence, the proposed typological model has been able to capture the major trends within the development of an emerging sector. For analysts, this model can form the basis of a systemic view to the variety of roles intermediaries (can) play in innovation systems and can lead them to both recognising the importance of organisations providing interventions previously excluded from the intermediation typologies as well as find gaps in such provision. Due to the limitations of this study - especially the limited empirical data - this analysis shows that significant insight could be garnered from heuristic uses of the proposed model, both on the level of intervention's classification (resources/activities, physical/social, systemic/direct), the proto-typological contexts (close involvement, systemic investment, soft leadership and strong mandate) as well as the emerging comprehensive typology of roles (enablers, equippers, shapers and movers). It is further important to note that the above interventions' objectives are underpinned by processes of social learning within intermediaries [49,50] and fitting wider innovation system development [15], hence this model could be deployed as a valuable tool in mapping intermediaries evolution in the current attempt to better understand the dynamics of innovation systems development and all actors contained within. Further studies as to the emergence of any comparative differences in provisions across different sectors within the same socio-economical and political context (i.e. locale, region, state) or in similar sectors in different contexts, could illuminate the variety of underlying factors in decision-making to implement any of the typified interventions [51].

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Annex 1 - Non-bridging Public Organisations in the Composite Whole Network of Scottish (New) Space Sector

Nodes (only non-private organisations: Innovation Intermediaries, *Research Centres* and Governmental and Non-Governmental Agencies)	In-degree Centrality (rank)
Adam Smith Institute	1 (8)
Aerospace Trade Body	1 (8)
Asia Development Bank	1 (8)
Cambodian Government	1 (8)
Cape Peninsula University of Technology	1 (8)
CeeD	1 (8)
Code Base	1 (8)
Digital Catapult	1 (8)
ECOSUR (Mexico)	1 (8)
Edinburgh Centre for Carbon Innovation	1 (8)
ESOC (ESA)	1 (8)
ESTEC (ESA)	1 (8)
FarmAfrica	1 (8)
Fishing Watch	1 (8)
Forestry Commission	1 (8)
Future Cities Catapult	1 (8)
Horizon EU	1 (8)
INPE (Brasil)	1 (8)
Ireland Space Centre	1 (8)
James Hutton Institute	1 (8)
JAXA	1 (8)
Luxembourg Space	1 (8)
Malawi Government	1 (8)
Mercy Corps	1 (8)
NOAA (US National Oceanic and Atmospheric Administration)	1 (8)
Offshore Renewable Energy Catapult	1 (8)
Philippine Government	1 (8)
Rothamsted Research	1 (8)
SCOPAC	1 (8)
Scottish Association for Marine Science	1 (8)

Nodes (only non-private organisations: Innovation Intermediaries, *Research Centres* and Governmental and Non-Governmental Agencies)	In-degree Centrality (rank)
Scottish Development International	1 (8)
Scottish Environment Protection Agency	1 (8)
Scottish Rural University College	1 (8)
Space Agency (Foreign)	1 (8)
Space Growth Partnership	1 (8)
Tontine	1 (8)
UK ATC	1 (8)
UN	1 (8)
University of Dundee	1 (8)
University of Glasgow	1 (8)
University of Manchester	1 (8)
University of Maryland	1 (8)
University of Nottingham	1 (8)
University of St Andrews	1 (8)
University of Wisconsin	1 (8)
Vietnamese Government	1 (8)
World Bank	1 (8)
Zero Waste Scotland	1 (8)